

**Human Creativity and the Case Against Regional Specialization:
Theory, Case Studies and Policy Implications.**

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Abstract

Regional specialization has long been thought to be both the logical outcome of market competition and the best geographical setting for innovation. Partly as a result of this belief, policies promoting regional specialization through "industrial clusters" have enjoyed worldwide popularity in the last decade. In recent years, however, a heated debate as to whether local diversity or specialization of economic activity is the best incubator of technological change and economic growth has been raging. Some authors argue that local diversity is more conducive to development through interindustry "dynamic knowledge externalities," while others pretend to show that local specialization, by allowing a better allocation of resources and/or increased competition is more likely to do so. One of the reasons that this debate remains so controversial is that there is no clear understanding of the processes by which knowledge "spills over" from a particular application domain to others. The purpose of this paper is therefore to point out some shortcomings of traditional approaches to the study of "knowledge spillovers" and to suggest an alternative based on how knowledge is actually created and exchanged by individuals. Evidence is drawn from the history of technology, some Baltimore cases related to research activities conducted at the Johns Hopkins University and from a survey of Southern Quebec inventors. Much available evidence illustrates how by offering a greater number and variety of problems to be solved, as well as much wider pools of knowledge and other resources, a diversified city is more likely to foster innovation. While the processes by which individuals combine resources in a new way occur spontaneously on a large scale, some policy initiatives that might increase these knowledge flows are then discussed. Our main proposal is to create an association of retired individuals with a proven track record in terms of industrial innovation that would visit plants in industries they are not familiar with to see if they could suggest improved ways of doing things based on their past expertise.

Keywords: Agglomeration economies, knowledge spillovers, human creativity, interindustry technology transfers, Johns Hopkins University.

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Executive Summary

In the wake of the success of regions such as Silicon Valley, many policy makers have tried to address the plight of older industrial centers by promoting the creation of “industrial clusters,” i.e. regionally-based concentrations of firms working in related lines of business. By increasing both competition and potential collaboration between related firms, such geographically based industries are said to facilitate widespread face-to-face interaction while reducing transaction costs.

This strategy, however, ignores one of the most fundamental aspects of any type of creative process, which is that innovation typically proceeds by combining heterogeneous facts, ideas, faculties, and skills. For example, when some production managers at *Northrop* were struggling to integrate a new composite in aircraft production that had to be kept refrigerated, one of them decided to call upon the refrigeration specialists at a nearby *Sara Lee* plant. The collaboration between the employees of these two firms ended up saving *Northrop* significant amounts in R&D spending.

While many authors still have to catch on to this paradox, in recent years a debate has arisen over the kind of “localized knowledge spillovers” that are more significant for technological change and economic growth at the regional level. One line of thought suggests that intra-industrial spillovers matter more and that an increased concentration of a particular industry within a specific geographic region is more desirable. This view can be said to be dominant

among policy-makers. By contrast, some analysts argue that the most important knowledge transfers at the regional level typically occur between industries, whatever they happen to be. This debate on the respective impact of local specialization and diversity on firms' innovative capacity has been one of the most controversial in the last decade in academic fields such as economic geography and urban and regional planning.

Scholars have until now attempted to settle the issue through the use of various econometric techniques. Some have presented evidence pointing towards the greater importance of regional specialization, while others argue that variety and diversity of geographically proximate industries promote innovation and growth. There are, however, a number of methodological problems in tracking "knowledge spillovers" using econometric techniques. Actually, even though the authors of these studies interpret their findings in terms of "knowledge" or "education," there is no direct evidence to that effect. One can therefore argue that this type of work alone will not settle this debate. The present study tries to remedy these shortcomings in at least two ways. First, it builds on insights derived from cognitive psychology and the history of technology that have so far escaped the attention of geographers, economists and regional planners. Second, it provides direct evidence on "interindustry knowledge flows" through a qualitative study approach that draws both on historical evidence and contemporary cases in the cities of Baltimore (Maryland) and Montreal (Quebec).

The case study evidence offered suggests that knowledge recombination occurs spontaneously and on a large in diversified local economies. Much of it takes place in teamwork within firms where specialists with different expertise collaborate with one another to create new products and processes. Apart from such "in-house" resource combinations, four other types of

interindustry knowledge spillovers can be observed: 1) a firm's employees add to, or switch, their product lines; 2) individuals move from one firm to another one to incorporate their previous know-how in a new activity; 3) individuals observe a product/process in another setting and incorporate it in their production; 4) individuals with different skills working for firms dealing with very different end products collaborate with one another to create a new process/product.

It is argued that if innovation is understood as the combination of previously unrelated things, it seems obvious that diversified cities will be more likely to generate innovation than specialized ones, even though, of course, specialists in one area often need to rely on the expertise of their colleagues. The best setting for innovation would then seem to be a diversified city made up in part of many specialized clusters – which is historically what important cities have been. Public planning that promotes specialization at the expense of diversity is therefore ultimately self-defeating, for it dries up the pool of potential ideas and skillful people on which innovators, working alone or in firms, can draw upon to combine unrelated things in a new way.

If the analysis presented in this paper is correct, a case can be made that the “industrial clusters” approach might not be the most productive. Indeed, there is much evidence demonstrating that any growing economy will become increasingly complex and diversified and that the exchange of ideas between specialists working in different industries will spontaneously occur. Forcing economic specialization might therefore be counter-productive. Is there, however, something that policy makers can do to promote knowledge flows across industries?

Before suggesting possible policy interventions, one must recognize that such knowledge flows across industries have always occurred spontaneously, mostly through individuals moving

between industries or through individuals observing something in a new light and using it to solve a particular technical problem. Almost three decades ago, however, Langrish et al. (1972) remarked that workers are often not looking widely enough for ideas. According to these authors, even though many people try to keep in touch with what is happening close to their own field of expertise and in related areas that seem relevant, they do less often look for other industries that might be experiencing similar problems. For example, bread baking and plastic foam manufacture are both concerned with the expansion and hardening of paste-like materials into solids. Yet, plastic foams technologists rarely attend the meetings of baking technologists to see if they might get any new ideas. Evidence gathered during the course of our case studies corroborates this assertion, as it was observed that many entrepreneurs, managers and technicians do not really know what their area's firms in other industries are about. Perhaps this is so because the peculiarities of each specialty that has its own vocabulary, culture and know-how that are not easily communicated to outsiders in the context of a trade show or an industry meeting. It might also be that the probability of hitting upon a "big idea" in a remote technological area that might have short-term pay-offs is simply too small for individuals who are otherwise very busy with their regular tasks.

While finding ways to make connections between different local industries might go a long way toward helping people see some new opportunities, overcome barriers and built on local strengths, it seems unlikely that people who are currently involved on a full-time basis in any line of work will have the opportunity to spend much time looking for ideas in remote fields. Any attempt to increase the current level of the exchange of ideas between different industries would then have to involve people who are both knowledgeable about particular industrial and commercial practices and who have enough time to visit plants in other industries and think

about new applications for their particular expertise – or else help questions current ways of doing things. For obvious reasons, retired people would seem logical candidates to fill in that role, for even though their knowledge base might be not be the most updated in their particular line of work, it might nonetheless prove sufficient to be useful in other industries. Furthermore, they might have the ability to open the doors of various executives that might otherwise remain closed, while their network of knowledgeable individuals that could facilitate new combinations might be very extensive.

Perhaps then an attempt could be made to create or build upon existing inventors or retired people associations or networks to take a first step in this direction. In essence, retired industry ~~personal~~ ^{personnel} with a proven track record of creative thinking could be encouraged to visit industrial facilities operating in sectors other than the ones they are familiar with. If this could be achieved, perhaps these outsiders with time and expertise at hand could suggest new ways of improving manufacturing processes or act as intermediaries between different industries. They might make themselves available as consultants if an approach seems particularly promising, or at least force some people to rethink widely held beliefs. While the particulars of such a strategy would have to be worked out in some detail for lack of precedents to build upon, we believe that such an approach might prove a more effective way to increase local networking and the innovative capacity of firms than previous approaches such as “industrial clusters.”

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Introduction

Regional specialization has long been thought to be both the logical outcome of market competition and the ideal setting for innovation. In recent years, however, a heated debate as to whether local diversity or specialization of economic activity is the best incubator of technological change and economic growth has been raging. Building on the work of Jacobs (1969), some authors argue that local diversity is more conducive to economic development through interindustry “dynamic knowledge externalities” (Feldman and Audretsch 1999; Glaeser et al. 1992; Harrison et al. 1996a; 1996b). On the other hand, other scholars argue that while localized diversity might sometimes play a role, local specialization allows a better allocation of resources and/or increased competition and is therefore more conducive to innovation and growth (Bostic et al. 1997; Henderson 1997; Henderson et al. 1995).

Most authors to date have dealt with “geographically localized dynamic knowledge externalities,” or “Jacobs’ externalities” as some economists have dubbed them, by arguing somewhat vaguely that the spatial concentration of diverse individuals increases personal interaction across economic sectors, which in turn generates new ideas, products, and processes. Yet, as Hansen (2000, 2) points out: “the extensive recent literature on the importance of dynamic knowledge externalities in cities, especially large cities, has not directly measured them.” Perhaps this is so because there is no clear understanding of the processes by which knowledge “spills over” from a particular application domain to others. The purpose of this report is therefore to point out the shortcomings of traditional approaches to this topic, to suggest an alternative based on human creativity and to further supplement these by anecdotal evidence derived from the work that I conducted while a Research Fellow at the Institute for Policy Studies.

In order to understand how knowledge is actually exchanged amongst individuals possessing different knowledge bases and the influence that a local environment might have on these processes, it is necessary to commence with a brief review of the traditional emphasis on regional specialization. Recent studies that support the diversity hypothesis will then be examined in more detail. The work of Jacobs (1969), who originally articulated the “dynamic” argument for the importance of local diversity, will then be assessed in light of the recent literature. One of the premises of her work is that economic classification systems are more confusing than helpful in understanding innovative processes, a point that is then examined in more detail. I attempt in the following sections to clarify and elaborate on Jacobs’ work by introducing further insights developed by students of technological creativity and a different literature on regional innovation. Further illustrations taken from innovative activities conducted in the Baltimore area that derived from academic research at the Johns Hopkins University, along with other case study material drawn from a survey of individual inventors in the Canadian city of Montreal, further illustrate these processes. The following section makes the case for a diversified city and against policy makers’ recent focus on regional specialization. The final section summarized current policy debates and draws some implication for policy-makers.

1. Traditional Approaches to Regional Specialization.

For more than a century, many geographers and economists have developed theories relating to the spatial agglomeration of economic activity in response to three empirical observations. First, a large portion of world output is produced in a limited number of highly concentrated core regions. Second, firms in similar or related industries tend to co-locate in particular places. Third, both of these patterns seem to be sustainable over time. For example, a book published in the middle of the thirteenth century describes various geographical concentrations of

producers in Medieval England (Marshall, 1952 [1920]: 223), while some contemporary American examples of regional clustering include Massachusetts' Route 128; New York's diamond, financial, advertising and multimedia districts; Minneapolis' medical equipment industry; and Chicago's future industries. The most studied case is, however, California's Silicon Valley (Malmberg 1996; 1997). Such geographic concentration of related firms is usually explained by positive externalities known as "agglomeration economies," i.e. the notion that firms can achieve greater efficiency and flexibility when they operate in the context of a local economy where they can draw on larger pools of labor, materials and services.

1.1 Agglomeration Economies

Agglomeration economies are of two types, those relating to the agglomeration of firms of the same industry in one area (localization economies) and those relating to the agglomeration of various industries in one location (urbanization economies). Geographical agglomerations of firms can be found at the city, neighborhood, or street level, usually depending upon the capital requirements an industry. Thus one can find automobile design studios located all over South California, although mostly in incipient agglomeration in Orange county and, to a lesser extent, Ventura county (Scott 1996),¹ whereas the fur districts of Montreal, New York and London are located in the heart of their cities (Julien 1991). It has also been noted that metropolises are typically patchworks of such "industrial districts." Thus citizens of Los Angeles can boast of districts specializing in the production of film and television programs, recording, advertising, printing and publishing, textiles and clothing, furniture, jewels, processed food, and biomedical products (Scott 1996). The scale of an industrial district is, however, subjective. For example, it can be argued that Los Angeles' entertainment district is made up of a number of sub-clusters,

¹ Southern California is now a major world center in that area with close to two dozen design studios belonging to American, European, and Japanese firms (Scott 1996).

such as animated films, special effects, photographic processing, sound recording, television programming, video production, film editing, and many others (Scott 1996: 312).

Following Marshall (1952 [1920]), most analysts usually highlight the fact that firms benefit from their location in such "industrial districts" by sharing the fixed costs of common resources such as a pooled market for workers with specialized skills, the development of specialized inputs and services, and technological spillovers. As Marshall's contemporary Charles S. Devas (1901, 98-99) wrote:

This kind of concentration is what is called *localisation of industry* in the strict sense. The grounds for it are manifold. There can be better technical training where many of the same trade are congregated together, more mutual help, greater likelihood of inventions, more use in common of markets, means of carriage, and machinery, and greater growth of *subsidiary industries*, such namely as supply materials and utilise refuse, to do which for a single factory would not be worth while. And in modern industry, especially where machinery is elaborate, it is a great gain to have close at hand those who can at once repair or replace any damage or loss of that machinery. Hence, although localisation is conspicuous in past economic history, different villages or towns having each as their specialty some particular trade, it is more conspicuous now when not merely thousands but millions of customers are supplied from one centre.

While each firm faces concern whether to make or to buy products and services, in a modern economy no firm can avoid buying inputs from diverse suppliers. Cities are therefore the hosts to many businesses supplying various pieces of equipment or services to diverse industries, a phenomenon known, as was pointed out, as urbanization economies. The spatial agglomeration of various activities will, for example, allow the operation of airports, hospitals or cultural activities, as well as law, accounting and various consulting firms of the first order. If the benefits of a greater division of labor between firms are well understood, geographical proximity between a supplier and its customers further increases the speed of delivery while allowing the possibility to make daily deliveries, to save the buyer warehousing space and to reduce the risk of running out of a needed item while it is being shipped from a long distance.

1.2 On the Persistence of Geographical Agglomeration

The geographic concentration of economic activity has existed since at least the Neolithic period (Mellaart 1967) and cities have since never stopped getting larger. Like today's "telecommunications revolution" prophets of the "Death of Distance" (Cairncross 1997) and the "End of Geography" (O'Brien 1992), however, most commentators have probably always believed that recent advances in transportation and communication technologies tend to nullify the impact of agglomeration economies. Thus even Alfred Marshall postulated that the railway, the printing press and the telegraph were working against geographic concentration. He wrote: "Every cheapening of the means of communication, every new facility for the free interchange of ideas between distant places alters the action of the forces which tend to localize industries" (Marshall, 1952 [1920]: 227). Another contemporary of Marshall, S. J. Hall (1900), similarly argued that the use of modern machinery tends to lessen the importance of a specially skilled labor supply and that the more an industry becomes automated, the more its location is likely to become independent of its supply of labor.

Economic history indeed teaches us that as an industry expands and becomes ever more sophisticated, the standardized production of geographically concentrated industries tends to be relocated elsewhere, either closer to consumers or to cheaper input sources (Haig 1926). But history also shows that as long as firms in an industry remain innovative, the forces of economic concentration usually remain much stronger than anticipated. Indeed, the overwhelming fact about past trends is that a general reduction in the transportation costs of both goods and information has always tended to encourage geographical concentration rather than discourage it. As Devas (1901, 100) observed at the turn of the century:

[The nineteenth century] revolution in transport by the introduction of steamships, and above all of railways, has ... produced as a portentous effect the concentration

of population in large towns instead of being scattered in villages or homesteads over the country. This disproportionate growth of towns is one of the most striking features of the nineteenth century, and is seen in every country where the new methods of transport are much used... The reason for the modern growth of great towns is simple. It is not that cities are much more attractive than before, but that the new means of communication have removed the obstacles to the operation of that attraction.

The case for the continued importance of geographical concentration is even stronger if one looks at service-based firms.² After all, trading foreign exchange over telephones and computer terminals can theoretically be done anywhere in the world - and is indeed done throughout the world. And yet, as the financial districts of New York and London can attest, the most innovative service firms are more than willing to pay some of the highest office rents in the world in order to be based in particular locations. The persistence of cities in spite of ever decreasing transportation costs (for both tangible goods and information) has in turn drawn the attention of scholars from a wide variety of fields, along with the development of new theoretical frameworks, as will now be illustrated.

1.3 The Rediscovery of Economic Geography

Once the sole province of economic geographers and regional scientists, regional growth and development theory has been supplemented in the last two decades by a number of new offerings, both theoretical and empirical, by business school professors, political scientists, economic sociologists and economists. In the wake of the spontaneous rise of some regions of the world which could not be accounted for by conventional theories, a large number of scholars have begun taking a new look at the industrial and social characteristics of a given place in providing (or not) fertile soil for economic development and technological innovation. Numerous frameworks have thus been developed that try to incorporate innovation in regional settings,

² Although, of course, the distinction between "manufacturing" and "service" firms is often arbitrary or lost in the statistical analysis of the location of activities.

ranging from contributions on industrial districts, innovative milieus and new industrial spaces to more recent theories (or synthesis) of regional innovation systems and learning regions. Researchers have in a first time emphasized how some regional settings balance cooperative and competitive forms of economic activity while also facilitating workers' mobility, new business formation, the development of trust relationships and easier access to start-up capital (Malecki 1997; Malmberg 1996). In the last few years, however, many authors have borrowed heavily from the literature on "collective" or "organizational learning" and have elaborated various approaches to the concepts of the "learning region".³ While it is beyond the scope of this report to review this literature in much detail, Malecki and Oinas (1999: 5-6) have summed up its main insights in the following way:

Under the condition of globalization... flexibly specialized networked actors... involved in collaborative and competitive relations... are embedded... in local social relations characterized by institutional thickness... where interactions is governed by conventions... and results in learning... within localized relations due to its tacit elements... and enables the creation of unique assets for competitiveness... of both firms and their regional environments

One of the most influential policy prescriptions that stemmed from this agenda has been the "cluster" strategy put forward by management theorist Michael Porter (1990). Porter views clusters as geographic concentrations of interconnected companies, specialized suppliers and service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate. He points out that the presence of clusters suggests that much of competitive advantage lies outside a given company or even outside its industry, residing instead in the locations of its business units. This focus on clusters naturally led him to argue that firms

³ It is beyond the scope of this essay to review this vast literature. For recent surveys, see Bergman and Feser (1999), Malmberg (1997), Moulaert and Sekia (2000) and Storper (1995), along with the special issues of the Cambridge Journal of Economics (volume 23, number 2, March 1999) and Regional Studies (volume 33, number 4, June 1999) on collective learning and regional development.

located within a cluster were more likely to attain competitive advantage, and that consequently public policy should promote the regional specialization of related activities. In the wake of different interpretations and adaptations of Porter's analysis, state and local development officials re-discovered agglomeration economies and established policies to promote specialization.⁴

A focus on regional specialization, however, ignores one of the most fundamental aspects of any type of creative process, which is that innovation typically proceeds by the combination of heterogeneous facts, ideas, faculties, and skills. The importance of such "interindustry knowledge spillovers" has long been recognized in various academic fields (De Bresson 1996; Pursell 1995; Rosenberg 1976). It is therefore not surprising that some researchers caught on to this paradox and began a debate on the virtues of specialization and diversity at the regional level that has been raging for almost a decade. One view (Marshall, 1952; Porter, 1990) suggests that intra-industrial spillovers are more important and that an increased regional concentration of a particular industry is desirable. By contrast, Jacobs (1969) argues that the most important knowledge transfers in cities come from outside the core industry there, whatever it happens to be. Thus in this view, it is generally not steel makers talking to steel makers that will come up with new applications, but rather metal-benders talking to cart-makers that will give rise to a bicycle industry. There are, however, a number of methodological problems in tracking knowledge spillovers using econometric techniques, as will now be illustrated.

2. Econometric Analyses of Localized "Dynamic Knowledge Externalities"

⁴ See Bergman and Feser (1999) for a description of the policy tools used to that end.

While recent empirical attempts to assess the respective impact of local specialization and diversity on economic growth by focusing on “dynamic knowledge externalities” have raised important questions, they have produced conflicting results and have been criticized on many counts. Hansen (2000, 3) succinctly points out their main problems: “The lack of consistent findings in these analyses is probably a consequence of their reliance on location quotients and similar measures of sectoral concentrations or diversity to explain employment, income or other growth measures that do not directly capture knowledge-related information flows and dynamic externalities.” For example, Glaeser et al. (1992) use wages and employment growth as dependent variables, assuming that they are measurable effects of innovation and new knowledge, when in fact their results cannot simply be interpreted in terms of knowledge and education (Quigley 1998, 136). This point is acknowledged by Coffey and Shearmur (1998) who use a similar methodology with Canadian data, but conclude more cautiously that diversified local economies generate more employment than more homogeneous ones.

Other researchers use indicators that appear more adequate, but can be proven intrinsically problematic nevertheless. Feldman and Audretsch (1999) rely on a United States Small Business Administration’s Innovation Data Base, which was compiled from a wide variety of industry announcements and trade publications. While this indicator has several advantages over indirect measures of innovation such as patent data, the authors point out that several important qualifications must be made regarding its use. The most contentious issues are a bias toward unusual and special interest product innovations and the considerable difference in the significance and quality of the innovations. Furthermore, their sample is probably biased toward the innovative output of larger firms who invariably benefit from better product advertisement resources. Harrison et al. (1996a; 1996b) use as their main indicators the adoption of a specific production process, computer programmable automation, by

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establishments belonging to 21 manufacturing industries (3 digit SIC level) whose product range extends from cars and aircraft to coffee grinders and scientific instruments. Yet the authors do not illustrate how the adoption of a new technology has more to do with "local diversity" than factors internal to an industry (including ideas originating from outside a given sector, but in another location) and firm (including multi-plant companies).

The controversy surrounding these research designs was somewhat predictable, for no recent article explores significantly beyond the methodological approaches used in earlier work on "interindustry technology flows" (De Bresson 1996; Scherer 1982) and the measurement of local diversity (Malecki 1997),⁵ two areas of research whose conceptual foundations were deemed largely unsatisfactory. Reviewing the conventional economic analysis of interindustry knowledge spillovers, De Bresson (1990, 833 my translation) writes that we do not know "what is measured, what assumptions and hypothesis underline the analysis, nor how innovation, invention or R&D are conceptualized in input-output tables." Malizia and Feser (1999, 2) make a similar assessment of earlier attempts to measure local diversity: "Economic diversity is the presence of multiple specializations. This definitional point deserves emphasis because the diversity literature is so confusing." Jackson (1984, 103) is even more critical and points to the issue of local diversity as typically "swamped by the measurement and estimation techniques employed" so that in the end "current diversity measures are deemed inadequate for regional policy makers."

Perhaps a more fruitful approach to the study of dynamic knowledge externalities should first address the processes by which individuals adapt specific materials, production processes and

⁵ Urban economists and geographers have long studied the issue of local diversity, but in a static way. The idea behind this line of inquiry is that diversified economy are less likely to be affected by industrial downturns and are

products in new environments. As Hansen (2000, 2-3) points out: "More meaningful analyses in this regard would require disaggregated empirical studies of how knowledge in fact passes among persons." I will now illustrate how many authors have addressed this issue, beginning with a more detailed review of Jacobs' case on behalf of local diversity.

3. Jacobs' Externalities, or Adding New Work to Old.

Even though Jacobs deals primarily with urban development and growth, her theory of technological innovation is firmly rooted in the study of human creativity, a process that she summarizes with the formula: "Adding new kinds of work to other kinds of older work" (Jacobs 1969, 51). Her case for urban diversity, however, goes beyond creativity and also includes entrepreneurship and agglomeration economies. Consider, for example, her discussion of the invention of the bra.

A custom seamstress, Mrs. Ida Rosenthal, was making dresses in a small shop of her own in New York. But she was dissatisfied with the way the dresses she made hung on her customers. To improve the fit, she began experimenting with improvements to underclothing and the result was the first brassiere. The customers liked the brassieres, and it became Mrs. Rosenthal's practice to give out a custom-made brassiere with each dress she made. Brassiere making, at this point, was still only a side issue to the dressmaking, a kind of accessory activity to the older work. But the fact was that Mrs. Rosenthal had become more interested in making brassieres than in making dresses, and while she was turning out dresses she was also making plans. She found a partner and together they raised enough capital to open and staff a workroom – a rudimentary factory – and Mrs. Rosenthal dropped dressmaking to devote herself to manufacturing, wholesaling and distributing brassieres. The new work now stood as an activity in its own right (Jacobs 1969, 51).

Limiting Jacobs' theory to "dynamic knowledge externalities" is therefore misleading. Even though there is no direct reference to Thomas Edison in her writing, the last excerpt could be interpreted as an endorsement of his famous motto that "invention is 1% inspiration and 99% perspiration," meaning that the idea for a new marketable device is but the genesis of the

lengthy process towards producing a viable commercial product. Much work, most of it entrepreneurial in nature, still remains to be done and it might be that urbanization economies are more important at this point.

Jacobs describes the processes of technology combination basing her theory on the premise that “the new work is added to older work first, and then sometimes its new divisions of labor are added to other appropriate varieties of older work” (p.52). Typically, however, “the new work is added directly onto only a fragment of the older work” (p. 55). Besides, “when new work is added to older work, it calls for more tasks in its own cause” (p. 56). It therefore becomes clear that “the greater the sheer numbers and varieties of divisions of labor already achieved in an economy, the greater the economy’s inherent capacity for adding still more kinds of goods and services. Also the possibilities increase for combining the existing divisions of labor in new ways...” (p. 59). How do people get ideas for new combinations? She proposes two possibilities that might occur to creative individuals: 1) ideas suggested by the materials or skills already being used; 2) ideas that arise from particular problems encountered in the course of the work (p.59). The two might sometimes overlap, but the processes are not necessarily automatic.

When new work arises from parent work, that in itself does not account for the new work. Many people do not attempt new solutions to the problems that arise in their work, nor do they glimpse new possibilities in the materials or skills they use. The creator of the new work must have an insight and, combining an idea or observation with the suggestion from the work itself, make a new departure. The point is that the logic of the process is supplied by the person who is adding the new work. And this logic comes in part from antecedent work which is almost always his own but, as we shall see later, is occasionally from someone’s else’s work that comes under his observation (Jacobs 1969, 60).

In Jacobs’ view, the logic of adding new work to old is always the logic of the producer, not of the customer. Furthermore, she points out that these processes almost always cut across

conventional classification systems: "The point is that when new work is added to older work, the addition often cuts ruthlessly across categories of work, no matter how one may analyze the categories" (p. 62). She therefore cautions against the use of economic classification systems: "These are useful categories for some types of economic analysis, but insofar as they are relevant at all to understanding how old work leads to new, they interfere with our understanding" (p. 61).

Jacobs's insights are well known to students of technological creativity, but have not been adequately addressed in the recent related literature in urban economics and regional science. For example, the use of industrial classification systems to assess the importance of interindustry knowledge spillovers is still widespread. This issue will be addressed before reexamining Jacobs' case by taking a more systematic look at the processes by which individuals combine older things to create new ones.

4. Industrial Classification and Technology Combination

As many authors have pointed out, the combination of previously unrelated things is the main difference between "natural" and "artifactual" evolution (Basalla 1988; Mokyr 1990; Sahal 1981; Weber 1992). In short, with the exception of the lowest levels of organization such as genes and microbes, different biological species do not interbreed, while artifactual types are relentlessly combined to produce new entities - a researcher can thus take genes out of a fish and put them in a strawberry. The anthropologist Alfred L. Kroeber illustrated this critical difference between living and human-made things more than half a century ago by sketching a "family tree" of organic species and another of cultural artifacts. In Kroeber's illustration, the species that form the different branches in the tree of life do not readily mix, but they split to form new species and remain totally isolated from one another once the "speciation" process

has been completed. By contrast, the branches of the artifactual tree fuse together to produce new types, which merge again with other branches. It could thus be said that a creative human being once had the idea to "mate" a tree and duck to produce a wooden duck decoy. Another way to look at this is to say that the internal combustion engine branch was joined with that of the bicycle and horse-drawn carriage to create the automobile branch, which in turn merged with the dray wagon to produce the motor truck. In principle, any invention can mate with any other invention, although the issue of commercial success is, of course, another matter.

On the other hand, the Standard Industrial Classification (SIC) system and the North American Industry Classification System (NAICS), with their definition of industry as a collection of firms producing a homogeneous product, are embedded in a "speciation" framework of evolutionary change. This approach can be traced back to Alfred Marshall (1952, 241), who built his industrial analysis on the concepts of "differentiation" and "integration" as understood by the biologists of his time. As he put it: "The general rule... [is] that the development of the organism, whether social or physical, involves an increasing subdivision of functions between its separate parts on the one hand, and on the other a more intimate connection between them." Such an approach can be useful to describe economic development at one point in time. It is not possible, however, to reconcile economic classification systems with the fact that virtually all functional processes and materials continually traverse "industrial branches" and that firms producing widely different outputs often use related production technologies.⁶

⁶ This was probably obvious to Marshall who, as will be pointed out later in this paper, was well aware of the "interindustry" nature of technical innovations. It must also be noted that Levinthal (1998, 218) defines "speciation" as "the separation of reproductive activity" and argues that "the application of existing technological know-how to a new domain of application" is a speciation event. Such an assertion, however, seems incorrect because the main characteristic of speciation is that the new organisms created through that process can no longer mate together to produce offsprings.

Another problem with industrial classification data is that they hide the multi-product nature of virtually all firms of any significance, along with the varied capabilities of their human resources. New combinations within firms are therefore ignored, even though such processes occur on a routine basis. For example, some employees of Canon's electronics and optics division have combined their skills to create significant innovations in cameras and photocopying machines (Galunic and Rodan 1997). Some of Sharp's employees developed the first commercially viable liquid crystal display for pocket calculators from the fusion of electronic, crystal, and optic technologies (Kodama 1992). If the real economic diversity of a geographical area is hidden when firms with diversified human resources are assigned a single code, it must also be kept in mind that industrial classification systems can hide the similarities between firms involved in the production of related products or services. For example, Porter (2000, 255) points out that Massachusetts' firms involved in the production of medical devices were "buried within several larger and overlapping industry categories, such as electronic equipment and plastic products." A case can therefore be made that a researcher studying local diversity is always the prisoner of the subjective criteria of the people who design industrial classification systems (Mills 1992, 7). The very structure of the SIC was a case in point, for it used both "product" and "production process" criteria to delineate various categories (Economic Classification Policy Committee, henceforth ECPC, 1993a) and it ignored as distinct categories important industries such as plastics and electronics (ECPC 1993b). Rosenberg's (1976, 15) warning, "It is necessary to discard the familiar Marshallian approach" when one seeks to understand how "certain functional processes... cut entirely across industrial lines" should arguably have been given more consideration.

A more interesting framework to deal with technology combinations is the patent classification system, which is based primarily on technological and functional principles and is rarely related

to economists' notions of products or well-defined industries. Thus a subclass dealing with the dispensing of liquids contains both a patent for a water pistol and for a holy water dispenser. Another subclass relating to the dispensing of solids contains patents on both manure spreaders and toothpaste tubes (Griliches 1990, 1666). Patent data, however, have important limitations, both in the way they are structured and in the limited coverage of technology that they provide.⁷ Their main shortcoming in relation to the study of how new combinations of resources are actually achieved, however, is that they typically do not tell us the "industry of origin" of an invention and often suggest a variety of uses that will never be materialized. Schmookler (1966, 23) described the problem many decades ago.

[A major] deficiency arose from the fact that I could not assign many [patented] inventions to a single industry. In part this resulted from my own ignorance, but often it reflected the interindustry character of technology. Thus, a given improvement in the diesel engine may be used in generating electricity or driving a locomotive, a given bearing may be used in shoemaking machine or a lawn mower, and a given knife may be used in harvesting or in kitchens. In consequence, the patent statistics used below generally do not include power plant inventions, electric motors, bearings, or other instruments or materials whose industry of origin was either multiple or simply not evident. Unfortunately, this means that the railroad data do not include inventions in the field of the steam or diesel engines, and that neither the farm nor the construction data include inventions on tractors.

Some patent office employees, most notably in Canada, have tried to correct this deficiency by assigning various industries of origin and of use to patent data. Patent office employees and inventors, however, can typically only guess some of the potential uses of a new device or material, and it is often the case that the most important use of an invention is very remote from its initial purpose (Basalla 1988; Jewkes et al. 1969; Smith 1982). In the end, as Griliches (1990, 1667) remarks, "most of the basic questions of classification still remain to be answered."

⁷ In short: 1) not all innovations are patentable; 2) not all patentable innovations are patented; 3) there are strong biases in the propensity to patent depending on the industry of origin, the size of the firm and the type of invention; 4) there are important reliability problems in patent data; 5) some patents prove to have an economic value, but the vast majority do not; 6) many patents are of a purely defensive nature; 7) patent requirements have evolved drastically over time and geographical space (Desrochers 1998; Griliches 1990).

One way to gain a better understanding of the processes of dynamic knowledge externalities is to drop conventional economic indicators such as firms and classification systems in order to examine in more detail some recurring patterns in the combination of previously unrelated technologies. In doing so, one must address the ultimate foundation of technological innovation, human creativity. If it is true that individuals work for firms and that much of their value to their employers is related to their belonging to various networks, each innovation ultimately depends to some degree on one person's knowledge and skills, as will now be illustrated in greater detail.

5. Human Creativity and Technology Combination

The etymological root of the Latin verb *cogito* (to think) is "to shake together", while that of *intelligo* is "to choose among" (Koestler 1969). The fact that all innovations are essentially novel combinations of existing devices and materials has therefore long been recognized. Not surprisingly, the adaptation of specific materials, processes and products from one area of industry to others unrelated in terms of final products, has also long been held an important aspect of technological innovation (Langrish et al. 1972; Rosenberg 1976; Pursell 1995; Smith 1982; Twiss 1980). It is thus believed that the bow-drill, which was used as much for drilling holes as for starting fires, led to the bow (McNeil 1996). In the last century, the concept of a production chain was adapted in flourmills, slaughterhouses and machine tool, canning, railroad and car assembly factories (Hounshell 1991; Klemm 1959; Mokyr 1990). Until the 1970's, physicians tended to adapt off-the-shelf materials designed for consumer applications. For example, a polymer called polyether urethane used in artificial hearths was originally used to make women's girdles. Dialysis tubing was originally sausage casing. In the case of breast implants, one type was actually a lubricant and another was a mattress stuffing. Fortunately,

the science and technology of synthetic polymers and biomaterials has progressed tremendously since then (Regalado, 1999). Laser is now used in, among other things, printers, telecommunication equipment, navigational instruments, textile machinery, surgery, precision measurement, weapon systems, sound systems and cash registers (Lipsey et al. 1998; Rosenberg 1996).

Many contemporary social scientists have addressed this issue by offering frameworks and concepts such as “technological convergence,” “technoeconomic paradigms,” and “general purpose technologies” (Lipsey et al. 1998). These approaches, however, are more descriptive than explanatory, because their authors usually fail to elaborate on the processes conducive to these transfers. The point of departure of each new combination is nonetheless very simple. As Petroski (1992, 22) defines it: “The form of made things is always subject to change in response to their real or perceived shortcomings, their failures to function properly. This principle governs all invention, innovation, and ingenuity; it is what drives all inventors, innovators, and engineers.” Furthermore, “since nothing is perfect, and, indeed, since even our ideas of perfection are not static, everything is subject to change over time. There can be no such thing as a “perfected” artifact; the future perfect can only be a tense, not a thing” (ibid.). Ultimately, according to Fores (1979, 853), the main thrust of an engineer or a technician is “to gather knowledge from diverse places in order to help solve technical problems.”

Gutenberg’s invention of the printing press affords a well-known illustration. At the dawn of the fifteenth century, printing was no longer a novelty in Europe. Printing from wooden blocks on vellum, silk and cloth is believed to have come into practice in the twelfth century, and printing on paper was widely practiced in the second half of the fourteenth. Oddly enough, though, the

starting point of Gutenberg's invention was playing cards on which a few words had been printed by way of rubbing wood blocks on a sheet of paper. As he wrote in his correspondence to a clergyman:

Well, what has been done for a few words, for a few lines, I must succeed in doing for large pages of writing, for large leaves covered entirely on both sides, for whole books, for the first of all books, the Bible. How? It is useless to think of engraving on pieces of wood the whole thirteen hundred pages... What am I to do? I do not know: but I know what I want to do: I wish to manifold the Bible, I wish to have the copy ready for the pilgrimage to Aix-la-Chapelle. (Koestler 1969, 122).

Gutenberg then searched for a device more resistant than wood block, which led him to notice the seals used to authenticate documents, but rubbing them on paper did not give a clear print. He found the solution one day, while attending a wine harvest near his city.

I took part in the wine harvest. I watched the wine flowing, and going back from the effect to the cause, I studied the power of this press which nothing can resist... God has revealed to me the secret that I demanded of Him... One must strike, cast, make a form like the seal of your community; a mold such as that used for casting your pewter cups; letters in relief like those on your coins, and the punch for producing them like the foot when it multiplies its print. There is the Bible! (Koestler 1969, 123-124)

Gutenberg, like all innovators relating known facts to each other by somewhat unconventional means, followed a few common transfer mechanisms. In essence, when combining resources in a new way, an individual uses his previous know-how and his capacity of observation and learning. He therefore has only two ways of combining different resources: 1) he can incorporate a new type of material/process/product (M/P/P) to a previously unrelated M/P/P; or 2) he can find a new use for a M/P/P. Gutenberg thus already knew how to work metal, a skill that he learned as the child of the Archbishop of Mainz's goldsmith. This skill undoubtedly facilitated the transition from wooden to lead moveable types, a process that required steel for letter punches, lead for molds, a tin-zinc-lead alloy for types and brass or bronze alloys for dies.

On the other hand, his observation and subsequent learning about a particular wine press provided the final breakthrough needed for the creation of the first functional printing press.

Despite the fact that inventions like the printing press may seem to be the work of a single human being, all innovations can ultimately be traced back to earlier products and techniques. Gutenberg thus had ready access to paper, presses, inks, scripts, alloys, woodcutting technologies and so on. Furthermore, most innovations require the collaboration of individuals possessing different skills. While more than one individual is typically required to solve any reasonably complex problems, it is imperative to acknowledge that all human minds function separately. As the psychologist Robert Weber (1992, 56) puts it: "Almost all important inventions are the work of multiple minds. But once we extract principles behind their development, it is possible to incorporate those principles into the individual mind, thereby giving us a leg up on the inventive process." I will now look at how individuals possessing very different expertise collaborate with one another, whether by working with other individuals in a firm, by collaborating with individuals working on different things for other employers or by moving among establishments producing different final goods and services.

6. Human Action and Resource Combination

6.1 Human Creativity and Multidisciplinary Team Work

It is generally accepted that multidisciplinary teams, by helping individuals overcome the blinders created by their particular expertise, most efficiently link concepts developed in one technology to problems arising in another (Schroeder et al. 1989; Twiss 1980). Twiss (1980, 69) thus explains:

One of the reasons for the effectiveness of the multidisciplinary team is that it brings together people working within different mental constraints. An extreme case of this comes from a large American research organization where one of the most creative

members is a former theologian. Inevitably many of his ideas cannot be translated into practical terms, but, occasionally, however, he does come up with a proposal which would not have resulted from the normal thought processes of his technological colleagues and yet proves to be technically feasible.

In short, as West (1991, 201) advances: "Sometimes it is good not to know beforehand all the reasons why something will never work and why it will never sell." Such teamwork is, of course, not limited to firms.

Apart from such "in-house" resource combinations, four other types of interindustry knowledge spillovers can be observed: 1) a firm's employees add to, or switch, their product lines; 2) individuals move from one type of production to another and incorporate their previous know-how in a new activity; 3) individuals observe a product/process in another setting and incorporate it in their production; 4) individuals with different skills working for firms dealing with very different end products collaborate with one another to create a new process/product. We shall now briefly examine each of them.

6.2 A firm's employees add to, or switch, their product lines

As Weber (1992, 104) has argued, finding new purposes for existing products and know-how is the "freest lunch that technology can offer." Carter (1939, 24) thus argued several decades ago that "one of the most frequent methods of employing inventive talent" is for an "expert in one branch of technology [to] intelligently investigate another field with the objective of discovering some application for his specialized knowledge." One should keep in mind, however, that substantial amounts of time and resources might nonetheless be required to achieve a commercially successful result. At any rate, expanding production lines is a dominant characteristic of any growing firm, for in countless instances creative individuals developed a

new technique in response to a particular problem only to later observe other possible applications. Rosenberg (1976) cites several such instances in the 19th century American and British machine-tool industries. Lichtenberg (1960) similarly reports that during the first half of the nineteenth century New York's shipbuilding manufacturers diversified to include making carriages, steam engines, and locomotives. Hounshell (1991) illustrated the point that in the 1890's, numerous buggy, railroad, toy, agricultural equipment, firearms and sewing machine manufacturers turned to the production of bicycles. More recently, Crevoisier (1993) has observed how in the last decades numerous Swiss clock and watch manufacturers have expanded their product lines to include such items as surgical tools, pacemakers, pens and insulin pumps. In some circumstances, however, it is necessary that skilled employees change jobs in order to continue to apply their know-how, as will now be illustrated.

6.3 Individuals move from one type of production to another and incorporate their previous know-how in a new activity

Whether initiated by employers or workers, the movement of skilled personnel between different areas of production is conspicuous throughout history as in the case of European clock makers who transferred their skills to numerous other activities in the late Middle Ages and early Renaissance. The phenomenon is also documented in the early British industrial expansion, most notably through the famous toolmakers of the "Bramah" dynasty (Mokyr 1990; Smiles 1863; Thomson 1991). Hounshell (1991) and Hoke (1990) similarly describe how American mechanics in highly productive factories passed those ideas on to others, who developed and utilized them expansively in numerous areas from the fabrication of axes to that of locks, from mechanical reapers to typewriters and sewing machines. Pursell (1995, 90-91) thus summarizes the spread of the notion of uniformity through the "migration of skilled workers from one industry to another." According to his analysis: "Such changing of jobs was typical of

American workers in general" (idem). The same process was also described in the United Kingdom by Alfred Marshall (1923, 10) in his classic *Industry and Trade*:

Modern work is more narrowly specialized, in so far as the number and variety of the operations performed by a modern worker are on the average less than those of elementary skilled handicraftsman; but it is less narrowly specialized, in the sense than an operative, who has mastered the accurate, delicate and prompt control of machinery of any kind in one industry, can now often pass, without great loss of efficiency, to the control of similar machinery in an industry of a wholly different kind, and perhaps working on different material.

Contemporary examples of this phenomenon are detailed in various studies on technological change. Langrish and his colleagues (1972, 44) give the following example:

An example of technological development of a new person joining [a] firm is to be found in English Electric's development of fuses for the protection of semiconductor devices. E. Jacks, then Chief Engineer in the Fusegear Division, had identified the area of printed circuit technology as an area, which might provide an answer to manufacture of the fuse elements. Progress was, however, held up because no one in the development team possessed enough skill in the use of photofabrication techniques. This need was overcome when, "by sheer luck," Jacks was interviewing an electrical engineer for a job and the applicant happened to mention casually that he had some skill in industrial photography which he had developed as a hobby. Photofabrication techniques were applied with great success and resulted in a completely novel process in the manufacture of fuse elements.

What may appear radical to those unfamiliar with particular techniques might be judged incremental by those in the know, hence the widespread belief in 19th century England that "major inventions were all the work of "outsiders"" (McLeod 1992, 290). Again, applying a particular know-how or material to a new situation might sometimes require considerable developmental efforts.

6.4 Individuals observe a product/process in another setting and incorporate it in their production

Gutenberg's invention of the first functional printing press is a well-known example of an individual observing a process in another setting and incorporating it in his own invention. Almost equally famous is the case of the car industry. It is thus generally acknowledged that the success of the Ford Motor Company owed much to previous developments in other industries, such as the production of interchangeable parts, the idea of continuous flow and the rise of an efficiency movement (Hounshell 1991; Klemm 1959). One industry that provided Ford's technical people a model of efficient material handling was the meat packing industry. According to the technology historian David Hounshell (1991, 241), William Klann, head of the engine department at Ford, recalled touring Swift's Chicago slaughterhouse and suggesting to superintendent P.E. Martin: "If they can kill pigs and cows that way, we can build cars that way and build motors that way." Klann also stressed that the Ford flow production drew upon the mechanical conveying system of both the flour milling and brewing industries: "We combined our ideas on the Huetteman & Cramer grain [conveying] machine[ry] experience, and the brewing experience and the Chicago stockyard. They all gave us ideas for our own conveyors" (idem). According to Hounshell, the process technology employed in food canning might also have inspired some of Ford's employees.

It would be a mistake, however, to consider that only industrial artifacts are useful in this respect. Consider, for example, the following anecdote related by a Soviet engineer:

For the ideal liquid for the hydraulic extrusion two mutually exclusive demands have to be met: in its zone of action for preparation the liquid should be non-viscous and should transmit hydrostatic pressure well, but in the zone of sealing and friction (where the plunger enters the container) the liquid should be highly viscous with good lubricating properties. We made numerous attempts to combine such a liquid of various components, we turned to the chemical institutes, patiently studied the literature and patents but did not succeed in finding a suitable liquid. The solution

came unexpectedly and at an institution most unsuited for scientific creativity, a cocktail bar. One Saturday evening we were distractedly looking at the manipulations of the lady bartender who was skillfully pouring multilayered drinks. At that time a stupidly simple idea came to me: what if a “cocktail” were to be made in the container for hydraulic extrusion too... We tried out and really it all went off excellently (Altshuller 1984, 252)

6.5 Individuals possessing different skills and working for different firms collaborate to create a new process/product

Exchange of technical information and informal collaboration between the employees of *competing* firms is widespread (Von Hippel 1988). It therefore seems likely that collaboration between individuals involved in totally different lines of work is even easier to accomplish and evidence exists of this. For example, in the 1980s aerospace manufacturers began using carbon composite material instead of aluminum to make tail sections, wings, noses and fuselages. Used first in tennis rackets and skis, composite material is just as strong but typically only weighs about half as much as aluminum. But it is also far more expensive and much more difficult to handle because if the composite material is not kept properly refrigerated before being cut to the proper shape, the material will be wasted. Properly refrigerating this material while in production, however, was no simple task. When production managers at Northrop began wrestling with this practical dilemma, one of them decided to call upon the refrigeration specialists at Sara Lee. Not long after that, knowledge and expertise gathered through decades of refrigerating large facilities became part of modern aircraft production technology (Rothschild 1990). Another illustration is given by an engineer working on the development of quantitative radiography for the Strategic Defense Initiative (better known by its nickname of “Star Wars”) who describes how he and his colleagues adapted their know-how to develop a more reliable digital mammography system for the early detection of breast cancer: “We had the answer, but we were looking for the question. We zoomed in into the medical imaging arena... We were convinced they were using 20-year-old technology.” The researchers, affiliated with Lawrence

Livermore National Laboratory, teamed up with an industrial partner with the relevant expertise to develop a commercially viable technology (Mellado 1999, 24). Similar examples are found amongst individuals working for electronic and fiber optic firms (Kodama 1992), as well as electronic and biomedical firms (Miller and Côté 1987), among others.

The importance of combining different resources in order to solve problems is nothing short of overwhelming. It will now be argued that geographical proximity between people possessing very different knowledge bases can sometimes facilitate these processes, but that current approaches to “learning regions” might not always be suitable to understand them. While it is beyond the scope of this essay to review these contributions in any substantive detail, some comments need to be made on the foundations of this approach and the way it has shaped some authors’ treatment of the influence of local diversity on knowledge combination.

7. Urban Diversity and Resource Combination: Theory and Case Studies

7.1 A Critique of Collective Learning

In essence, the literature on collective learning builds on the premise that innovation does not primarily derive from individual actions of combination, adaptation and extension, but results from embedded processes that are collectively organized by industries and networks of relations between firms, educational institutions and public authorities. Some authors have thus noted that the most significant difference between Marshall’s classic contribution on industrial districts and more recent offerings is a shift in emphasis from “individualistic initiative and free enterprise” to one that focuses instead on the “collectivist and institutional basis” of regional innovation (Keeble and Wilkinson 1999, 298). A “learning region” is thus viewed as nexus of “untraded interdependencies” (Storper 1995) which “extend beyond traditional customer/supplier relationships and encompass formal and informal collaborative networks,

interactions through local labor markets, and shared conventions and rules for developing communications and interpreting knowledge" (Keeble and Wilkinson 1999, 299).

While it may be true that some students of technological creativity have in the past neglected the formal and informal institutional setting of innovative activity, a case can be made that the recent emphasis on collective learning has led researchers to overemphasize the importance of firms, networks and regions to the detriment of human creativity.⁸ As Hansen (2000, 17) points out: "Regions, networks, and information technologies are not entities that can learn or innovate. What is required above all are persons who can recognize the significance of information and knowledge and use them to innovate successfully." One could thus argue that a perspective according to which firms (however defined)⁹ innovate can rapidly lead to analytical error. For example, Capello (1999, 355) takes such a perspective and writes: "In large enterprises, R&D functions and engineering departments play the role of information collection, its assessment and transcoding and the selection of decision-making routines." Yet, it is often the case that individuals involved in marketing are in a unique position to gather relevant knowledge on what problems and deficiencies should be addressed (Gordon, 1993: 42). Furthermore, individuals often move laterally between different departments and divisions within a firm. They do not become creative (or not) as soon as they enter (or leave) a particular division. Besides, individuals working for large firms frequently move to different geographical locations in the course of their career, each time for the explicit purpose of bringing their

⁸ For more detailed introduction to psychological perspectives on creativity, see, among others, Detterman and Sternberg (1993), Glover et al. (1989) and West (1991). For the specific issue of technological creativity, see Weber (1992) and Weber and Perkins (1992).

⁹ Another problem in this literature is the lack of a clear description of the firm. For example, Noteboom (1999, 129) provides the following definition: "According to the resource/competence view, a firm is to be seen as a configuration of technology and organisation... The firm is made up from a number of resources, consisting of assets, competences and positional advantage, embodied in various forms of capital (financial, human, social, commercial), which to a greater or lesser extent are specific to the firm."

particular expertise along the way. A similar case can be made against networks, if only because an individual can leave one, enter another, belong to many or simply use a phone book, an industrial catalogue or a web search engine to locate potential collaborators. Perhaps even more problematic for proponents of the “learning region” perspective is the fact that virtually all innovative firms are part of wider national and global networks and it is often the case that these distant partners, customers and suppliers matter more than those located in close geographical proximity. 10

In short, cities and regions are nexus of exchange where individuals belonging to various firms and networks interact in different ways and on different geographical scales. Specific firms, networks and regions create an environment that influences individual creativity, but they are components of the setting of the creative process, not its active agents. This is not to deny their importance, but it may be that the neglect of individual creativity explains why the “theoretical concepts underpinning these models [of “learning regions”] are used in a very ambiguous way” (Moulaert and Sekia 2000, n. p.) and that an unambiguous differentiation between “collective learning” and “learning” is still lacking (Capello 1999, 354). Despite such ambiguities, many recent contributions nonetheless highlight the importance of local diversity for the combination of knowledge. These will now be looked at in more detail.

7.2 Learning Regions and Resource Combination

Many authors who have worked on the thematic of collective learning and regional innovation have highlighted some features of creativity that have been described in previous sections,

10 See, among others, Cornish (1997), Hansen (1995), Keeble, Lawson et al. (1999), Malmberg (1996; 1997), Maskell and Malmberg (1999).

including the importance of novel combinations¹¹ – although virtually all of them have ignored Jacobs' (1969) pioneering contribution.¹² Indeed, just as any detailed case study of technological innovation is bound to illustrate new combinations, so are studies on regional innovation. For example, Meyer's (1998, 41) discussion of the formation of technology districts in New England at the turn of the 19th century contains the following description: "Private firearms firms had used their social networks ties to iron foundries, machine shops, cotton mills with textile machinery mechanics, and textile machinery firms to adopt innovative machinery. Information about those innovations moved fluidly because key individuals within local social networks... served as bridges among the networks." Similarly, in their detailed analysis of the British motor sport industry, Pinch and Henry (1999, 822) trace the rise of "Motor Sport Valley" to "the knowledge, physical inputs and skilled workers... [that] were all derived primarily from the fields of aerospace rather than mass produced car manufacture."

Despite a growing appreciation for learning processes, however, it may be that some economic geographers' long-standing focus on common behavioral practices and regional specialization might affect their appreciation of the combinatory process. Consider, for example, the following comments by Noteboom (1999, 144), who discusses combinations in the context of an industrial district rather a diversified city:

Concerning opportunity, and taking into account the role of distance discussed earlier, novel combinations are promoted by a constellation of separate, relatively small, weakly connected, spatially proximate units in complementary activities ("industrial districts"). In such constellations, a number of requirements are satisfied. Sufficient cognitive proximity (to be able to understand each other) and trust (to do without complex, detailed, costly, constraining contracts, and to contain risk of spill-over) is achieved on the basis of shared norms and values of conduct, the bonding of family, clan or friendship, and efficient reputation mechanism, the "shadow of the future" from expected dealings with each other in the future, shared

¹¹ See, among others, Capello (1999), De Bernardy (1999), Lawson and Lorenz (1999), Maskell and Malmberg (1999) and Noteboom (1999).

¹² One of the few exceptions is Perrin (1992).

routines. Sufficient cognitive distance (to offer each other novel insights) is achieved by variety in activity and experience. There is sufficient spatial proximity to allow for frequent and varied contacts, and for intensive interaction in partial joint production, needed for the transfer of tacit, procedural knowledge, which is characteristic of the early stages of innovation.

Lawson and Lorenz (1999, 307) also observe that learning depends on combining diverse knowledge, but argue, building on the work of evolutionary economists Nelson and Winter (1982), "that innovation depends on searching for new knowledge in close proximity to the organization's existing knowledge base." Feldman and Audretsch (1999, 412) similarly postulate: "Of course, there should be some basis for interaction between diverse activities. A common science base facilitates the exchange of existing ideas and generation of new ones across disparate but complementary industries."

Yet, perhaps it is not so much "knowledge proximity" that matters, but rather the possibility of frequent interaction between people with different background. As Feldman (1994, 21) points out, individuals with different expertise have different cognitive schemata. Interpreting and synthesizing information in this context involves constant questioning and interpretation through a process of trial, feedback and evaluation that is facilitated by face-to-face communication. Because most of the time individuals with different backgrounds working on the same problem do not even share key concepts, there is typically a need to develop a common language in order to coordinate search and development procedures. Such a process, however, does not entail insurmountable obstacles. Raymond Kurzweil, a pioneer in the field of electronic music synthesizers, relates some difficulties in getting linguists, signal-processing experts, VLSI [very large scale integration] designers, psycho-acoustic experts, speech scientists, computer scientists, human-factors designers and experts in artificial intelligence and pattern recognition to work together in his plant:

Each one of these fields has very different methodologies and different terminologies. Very often a term in one field means something else entirely in another field. Sometimes we even create our own terminology for a particular project. So, enabling a team like that to communicate and solve a problem is a significant challenge. If you look at the entire company, you bring in even more disciplines: manufacturing, material-resources planning, purchasing, marketing, finance, and so on. Each of these areas has also developed sophisticated methodologies of their own that are as complex as those in engineering. My challenge is to provide a climate in which people with different expertise can work together toward a common goal and communicate clearly with one another (Brown 1988, 243-44).

It would therefore seem plausible to believe that the local presence of unrelated activities might not only enhance the capacity of individuals to see new possibilities, but also to act upon them in the way described in this paper. As Aitken (1985, 15-16) remarks in his history of the radio:

A hypothesis worth testing is that the points of confluence of information flows define the social locations where there is a high probability of new combinations being made... Such an approach avoids determinism: it gives no warrant for asserting any kind of necessity in the process. But neither are we thrown back into blind chance. It is a matter of probabilities: the probabilities of new combinations being formed is higher at the points of confluence than it is elsewhere.

It might also be that the size of a diversified city plays a role, or that there might often be some “diversity threshold” in turning an idea into a successful commercial venture. Further evidence drawn from a work-in-progress currently conducted on the technology transfer operations of the Johns Hopkins University and a survey of individual inventors in the city of Montreal and Southern Quebec will now be examined.

7.3 Case Study Evidence: Baltimore, Maryland and the Johns Hopkins University

Johns Hopkins University is a somewhat small, but highly diversified,¹³ research institution located in an old industrial city that, despite some economic downturns, still harbors a relatively diversified economic base. Innovative activity conducted in this setting is therefore likely to

¹³ For a survey of the Johns Hopkins University’s various lines of work, see www.jhu.edu.

facilitate new combinations of existing expertise and devices. Such instances were found in the history of this institution, while contemporary cases were examined between October 1999 and April 2000. The previous sections built in no small extent to insights that were gained by the author during his time as a Senior Research Fellow at the Institute for Policy Studies. This section will therefore be limited to further illustrations and comments.

As can be expected, all creative individuals interviewed in Baltimore recognized the importance of finding new uses for their expertise and of combining existing things in a new way. A good example of the former is Marc Donohue, currently associate dean for research in the department of chemical engineering. Over the years, M. Donohue has acted as a consultant for very different firms, such as, for instance, E.I. du Pont de Nemours, Exxon Research and Engineering, Kodak Research Laboratories, Nabisco and Union Carbide. As he pointed out in the course of an interview, he transferred much knowledge acquired while working for on particular problem for one industry to another through the normal course of his consulting work. Another interesting example of this process, but this time in a spin-off context, is EntreMed whose "inventive paradigm" explicitly states the need to think "out of the box".¹⁴ As such, its researchers found a new use for thalidomide, the infamous sedative banned in Europe in the 1950's because it caused birth defects when taken during pregnancy. The reason why thalidomide turned out to be such a nightmare paradoxically proved to be its virtue. In essence, it was discovered that the very property that induced birth defects, i.e. ~~that~~ ^{the} fact that thalidomide blocks new vessel growth, might actually help cancer patients by starving the growth of tumors. Furthermore, thalidomide can also prove beneficial for elderly citizens and diabetics because blocking new vessel growth might actually prevent blindness. The firm is now a pioneer in the discovery, development and commercialization of antiangiogenic therapeutics, which is the

name given to this process, and its employees are, of course, busily finding new uses for their expertise. According to the company's website:

EntreMed's second commercial opportunity is nearing clinical trials with a device that processes red blood cells and may enable them to increase tissue oxygen delivery threshold. The company developed an instrument and a disposable component that separates blood cells and then makes them permeable to molecules of inositol hexaphosphate (IHP)... Furthermore, this core cell permeation technology has many other potential medical applications, allowing additional risk diversification for this product.

Another interesting spin-off case where new uses for existing expertise were developed is Neuristics. In essence, this firm first built on a form of artificial intelligence modeling developed for biomedical instrumentation by a Hopkins graduate student, Andrew Krause, and applied it to develop predictive modeling for credit card issuers. Since then, the company has expanded and developed expertise in a number of statistical and computer tools, such as Bayesian networks, case-based reasoning, clustering, evolutionary optimization, expert systems, feature extraction, fuzzy logic, learning vector quantification, neural-fuzzy systems, neural networks, operations research, rule induction and statistical inference. As can be read on the company's website:

[At Neuristics] we isolate and define underlying drivers, and identify their dynamics. We take the time to understand domains. We take the time to experiment and combine diverse techniques to create the best hybrids – hybrids that extract fundamental data often overlooked or neglected in today's complicated world, data essential to successfully managing the life cycle of your accounts. At Neuristics, we build complex hybrids that empower you – decision support tools designed for your future.¹⁵

As M. Krause pointed out in an interview, the main reasons for finding new uses was, at first, simple survival. In recent years, however, the firm activities have been more focused on specific lines of work as specific tools were developed. M. Krause also points out that

¹⁴ See www.entremed.com.

¹⁵ See <http://www.neuristics.com>

geographical proximity with its customers was not deemed primordial, for they can be found nation-wide and no particular regional concentration would have warranted a relocation of the firm.

Other interesting cases of new uses for existing technologies are Lion Pharmaceuticals that applied recent advances in drug discovery technology to genomic discoveries and Brassica Sprout Group LLC, a joint venture between JHU biochemist Dr. Paul Talalay and the Sholl Group II, a leader in the fresh produce industry. One can also point to MetaMorphix, which develops and commercializes genetically-related molecules involved in regulating cell growth and differentiation to various parts of the human body, such as neuromuscular disorders, muscle wasting, liver repair and regeneration, female infertility, and immune regulation. Of course, it was not long before the company executives found that their expertise had potential for increasing muscle mass in cattle and began expanding in this area. One of the goals of the firm's managers is now to find a way to produce meat more economically, with less fat and perhaps eventually without the need for antibiotics and hormones.¹⁶ Again, however, the absence of a significant cattle industry in Maryland has implied collaboration with producers located at some distance from the company's headquarters. Another case of adaptation of a technology in a new context is the Low Vision Enhancement System (popularly known as "Elvis") for visually impaired individuals that was devised by Hopkins ophthalmology professor Robert Massof based on gear created by the National Aeronautics and Space Administration in another context. Dr. Massof improved on the NASA device by collaborating with engineers from Hopkins' Applied Physics Laboratory, former employees of military contractor Honeywell and scientists at the University of Waterloo (Canada). As of this writing, however, the product was not yet financially successful. Other unsuccessful examples of inter-industry technology transfer

what about Sholl?

include Applied Physics Laboratory [APL] research teams experiment with a hypersonic gun tunnel built on the theory that subway trains in underground tunnels were subject to the same physical forces as missiles in a gun barrel (Klingaman, 1993: 214) and attempt to develop urban mass transit by applying expertise in propulsion theory (idem, p. 215).

A good example of an individual combining various types of knowledge in a new way is biomedical engineer Patrick Jensen, the co-director of the Microsurgery Advanced Design Lab (MEDLab), who works to join electromechanics, optics and software in order to extend the limits of the surgeon's perception and dexterity. As he points out, such an approach is not surprising considering that the eye is itself a combination of optics, mechanics and electronics. But while the MEDLab team combines new things in Baltimore, it is also involved in National Science Foundation-sponsored collaboration with MIT and Carnegie-Mellon on computer-enhanced surgery.

Creative endeavors where individuals possessing different skills collaborate with each other are, of course, not limited to contemporary spin-offs. Actually, Hopkins history is replete with such instances. For example, Arnold R. Rich, a professor of pathology, wrote in 1948 that he had been "fortunately situated" for the "pleasures of the cross-fertilization of thought between colleagues in different fields" (Harvey et al. 1989, p. 262). By this, however, the Hopkins scientist referred to collaborators in other divisions of the Johns Hopkins Medical Institutions. In a more striking example, physicians from the Medical School and professors from the Engineering school collaborated for the development of ultrasonic instruments for eye and brain surgery and the use of telemetry and computers to monitor hospital patients. Meanwhile, researchers based in the School of Hygiene and Public Health entered in an unlikely alliance

with faculty at the Peabody Institute (a music conservatory) to collaborate on environmental sound studies (Schmidt 1986).

In some instances, physical proximity facilitated communication between people possessing very different expertise. Former Johns Hopkins president, Milton D. Eisenhower (1973, 26-27), describes how such a situation occurred many decades ago.

[APL director Frank McClure] initiated a collaborative attack by engineers, physicists, and medical scientists on problems in ophthalmology, cardiology, prosthesis, radiology, and diagnostic medicine, among others... The initial problem had to do with cataract patients who sometimes could have unsuccessful operations because one could not tell in advance whether the optic nerve at the back of the retina was viable or had degenerated and thus could not transmit messages received through the lens of the eye to the brain. In the first conference, medical and APL scientists could not understand one another. The modern Tower of Babel – the specialized jargon of each intellectual discipline – was a barrier. But three long discussions produced a common language and genuine understanding.

Examples illustrating the reutilization of past know-how in a new way are also conspicuous. For example, William Osler, Hopkins first professor of medicine, was simultaneously appointed physician in chief to the hospital, an office first devised by the president of the university on the basis of his experience of running a large department store.¹⁷ This model later spread to most medical centers of the United States.

In other cases, however, geographical proximity doesn't seem to have been a major issue. Evidence of this can be found in numerous collaborative partnerships between individuals based at the APL and their associate contractors that were often located in other regions. For example, to help APL design a suitably durable radome (a radar-transparent "windshield" that covered the homing antenna within the nose of a missile), one project manager enlisted in the mid-1950's the aid of the Corning Glass Corporation, which had extensive expertise in working

with hardened, temperature-resistant, glass-like materials, but was based in Upstate New York. After having tried, and failed, to find a suitable existing material, Corning offered to develop something entirely new if APL's project manager would give their technicians the specifications it required. Corning's employees eventually developed two new materials. One of these proved suitable to solve APL's problem, but it was also eventually marketed by Corning under the label Pyroceram who used the formula developed for APL to produce a new line of best-selling temperature-resistant ceramic cookware (Klingaman, 1993: 98). Other new uses for devices created by or for APL that did not seem to have required close geographical proximity with collaborators include a satellite navigation system that was used to map wilderness areas (p. 198), a radar automation system that was applied to harbor traffic control (p. 215) and expertise in the corrosion of satellites and submarines that was applied to a natural gas pipeline system (p. 240).

In general, it can be said that knowledge combinations is recognized as a vital part of the creative act by all the individuals interviewed during our stay in Baltimore. Furthermore, all of them agree that finding a new application for a given expertise is indeed the freest lunch that technology can offer. In most cases, however, physical proximity does not seem to play the role that the recent literature in economic geography would have us believed, because many firms and research teams have formal linkages with partners in other locations. For example, Physiome Sciences, a JHU licensee technology based in Princeton, New Jersey, has developed strategic alliances with leading modeling physiology groups including those at the University of Oxford and the University of Auckland (New Zealand).¹⁸

¹⁷ From the "Osler, Sir William, Baronet" entry of the *Encyclopedia Britannica Online*.

¹⁸ See www.physiome.com

While much has been written on the respective importance of intra and inter-industry knowledge spillovers in recent years, there has been only one other detailed qualitative survey that examined both technology recombination and the importance of a diversified local economy on these processes. Its main finding will be summarized in the following sub-section.

7.4 Case Study Evidence: Montreal and Southern Quebec¹⁹

This section will further illustrate the processes of “interindustrial knowledge spillovers” through anecdotal evidence collected in a survey of 45 Quebec inventors that was conducted between May 1997 and March 1999. While the evidence presented is anecdotal, the patterns illustrated are typical of what was observed throughout the sample.

The sample of individual inventors was chosen to reflect as closely as possible the proportions of urban and rural population of Southern Quebec. The inventors’ average age was 55 year old in 1999, with the youngest individual surveyed being 33 and the oldest 86 year old. 4 inventors were less than 40 year old, 33 were between 40 and 64 year old and 8 were over 65 years of age. 43 out of 45 inventors were French-Canadians, while 21 of these individuals claimed to be bilingual (48%), a proportion that is significantly higher than the provincial average of 35%. While only 4 women were included in the sample, this proportion is widely acknowledged to be representative of the world of invention. 28 individuals (62%) were full-time inventors, but most of these (18) were retired and did not earn a living from their creative work. The 17 remaining individuals (38%) had a regular job that was in a majority of cases, but not always, closely related to their current inventive project(s). 4 inventors were engineers by training (one electrical, two mechanical and one production engineer), but the majority had the equivalent of a community college certificate in a technical area such a welding, industrial design, electricity,

plastic molding and electronics. A few individuals had no technical training at all. It must be pointed out, however, that most of the individuals interviewed took numerous continuing education classes on a wide variety of topic throughout their adult-life. It was therefore not possible to compile detailed information on their formal educational level. Of course, all these individuals had acquired valuable experience through "on-the-job" formal and/or informal training. 60 inventions were documented in more detail. They included 51 consumer goods, 2 industrial processes and 7 that were both industrial and professional products.

Despite very different characteristics and background, regularities were observed in all of these individuals' creative process. To summarize, all inventors went through the following steps, often going back and forth between these: 1) Problem identification; 2) Looking at many different ways of dealing with a problem; 3) A trial and error phase;²⁰ 4) New combinations; 5) The absence of a definitive solution. Individuals had only two ways of combining existing products, processes and materials in a new way: 1) To find them a new use; 2) to incorporate them into something else. All individuals admitted that they frequently borrowed and adapted existing products, processes and materials in a new way, whether while working on a particular innovation or in various production processes.

How did individuals find a new use for their particular know-how? The most common way was through job mobility. In essence, creative individuals that lacked the credentials²¹ or the interest to climb a corporate ladder²² often changed jobs and industrial sectors either because

¹⁹ See Desrochers (2000) for the detailed methodology and complete results.

²⁰ Unlike scientists, technicians can never make simplifying assumptions.

²¹ Among the most common causes that prevented individuals for climbing the corporate ladder was a lack of college education or an inability to speak English.

²² A number of individuals thus passed on promotions to positions that involved primarily managerial tasks for a lack of interest in this kind of work.

they lost interest in their line of work, lost their job or saw a more promising opportunity elsewhere. For example, a machinist moved between the steel, chemical and aerospace industries, before spending some time in porcelain making and real estate. A production engineer began his professional career in a textile plants and later moved on to a cement factory, a nuclear power plant, a governmental development agency and a garage door manufacturer. A mechanical engineer got his start in an ore processing plant and later worked for a car plant, a truck plant and a plastic manufacturer. He summarizes the comments of many individuals interviewed when he pointed out: "I was never able to stay more than 2 or 3 years at the same place... After 2 or 3 years, I knew everything. I had done everything. I needed new challenges. I was soon looking elsewhere."

This spontaneous process of job mobility in turn led to innovations in a new setting where solving problems by using past expertise became an almost unconscious habit. As an engineer put it: "You always bring various experiences and know-how from one field to another... Whether in mining, plastic molding, car manufacturing... You need pumps, compressors, pipes, etc. You can often apply something that you learned in one place to another." A draftsman who used his expertise in truck, pulp and paper processes gives another illustration, saw mills and railroad wagon design to come up with a new type of bicycle. Similarly, a machinist who used to work in a newspaper printing plant suggested a new way to clean asphalt tankers based on his previous expertise.

Another frequent mechanism leading to new knowledge combinations was, as was pointed out, the discovery of a new use for an innovation. One individual thus adapted a signaling device that he had created for a credit union confederation for use in the restaurant business. Another inventor modified a device made of large rules and electronic components that was originally

created to assess car crashes in order to use it in archeological excavations. One individual found that there was a demand for new type of ski rack that he had created to display other types of sporting equipment once three or four of these racks were put on top of each other.

In the end, however, whenever individuals tried to adapt something in a new context, the network of knowledgeable people that they had built over the years while working in different industries often proved to be their most crucial asset, for no matter how straightforward adapting a particular piece of know-how might have seem, a long and arduous development process was often needed before coming up with a commercially viable product or way of producing it.

In essence, “interindustry knowledge spillovers” occur spontaneously because: 1) the nature of human creativity, which is based on the new combination of older things; 2) creative individuals quickly get bored with routine work; 3) finding a new use for his specialized know-how is one of the most sensible way for an individual to create innovative products and processes. Some policy implications will now be derived from these observations.

8. Policy Implications

8.1 Human Creativity and the Case against Regional Specialization

If innovation is understood as the combination of previously unrelated things, it seems obvious that diversified cities will be more likely to generate innovation than specialized ones, even though, of course, specialists in one area often need to rely on the expertise of their colleagues. The best setting for innovation would then seem to be a diversified city made up in part of many specialized clusters – which is historically what important cities have been. Specialists of regional growth relying on theoretical models, on the other hand, have typically stressed that competition is more likely to promote regional specialization. It can be argued, however, that

such a view is plausible only in a static world where resources are given and allocative efficiency is the main driving force. In a dynamic world where new things are created and older ones rendered obsolete, regional specialization occurs spontaneously, but the main characteristic of a growing regional economy is that it becomes ever more complex and diversified. Public planning that promotes specialization at the expense of diversity is therefore ultimately self-defeating, for it dries up the pool of potential ideas and skillful people on which innovators, working alone or in firms, can draw upon to combine unrelated things in a new way.

The thesis that local specialization might be more conducive to innovation must ultimately rest on the belief that new ideas are useful only within an industry. This is obviously untenable, both in view of how individuals generate new know-how and how quickly some individuals have always found new uses for their particular expertise. The theory of comparative advantage and its application at the regional level are based on the sound principle that the division of labor leads to greater efficiency. Perhaps, however, the division of labor should be more often considered in terms of the particular skills that individuals possess rather than the final goods they produce.

If the analysis presented in this paper is correct, a case can be made that the “industrial clusters” approach might not be the most productive. Indeed, there is much evidence demonstrating that any growing economy will become increasingly complex and diversified and that the exchange of ideas between specialists working in different industries will spontaneously occur. Is there, however, something that policy makers can do to promote interindustrial knowledge spillovers? The last sub-section will look at some possibilities.

8.2 Some Policy Suggestions

Before suggesting possible policy interventions, one must recognize that “interindustrial knowledge spillovers” will occur spontaneously, mostly through individuals moving between industries or through individuals observing something in a new light as they try to solve a particular technical problem. There is probably little that needs to be done, or can actually be done, to increase the volume of these processes. Furthermore, some things are clearly beyond the reach of policy makers. For example, there is little that local economic development experts can do to promote the exchange of ideas between different specialists working *within* a firm or an institution.

One must recognize, however, that the collaboration of individuals with different expertise is typically a more difficult endeavor in the academic world than in the private sector. Rosenberg (1994, 152) thus points out that the managers of the best industrial laboratories, unlike university research authorities, have traditionally placed a high value and considerable recognition on individuals who are useful in solving the problems encountered by colleagues in fields other than their own. In the academic world, the issue of interdisciplinary work has always been a contentious one, for collaborative work between different specialists often goes against the disciplinary boundaries that are reinforced by peer-reviewed and promotion processes. Actually, it might be that traditionally the Johns Hopkins University has been rather good by academic standards at facilitating interdisciplinary work. It can nonetheless be pointed out that new approaches to deal with interdisciplinary work are currently being developed in other institutions and promoted by funding agencies, such as the National Science Foundation, and these might contain useful lessons for Hopkins and other local universities and colleges (Service, 1999). One suspects, however, that Baltimore college administrators are certainly aware of this issue and already have answers of their own.

Is there, however, an approach that would increase the exchange of ideas between individuals with different expertise? Perhaps. Almost three decades ago, Langrish et al. (1972: 48) remarked that workers are often not looking widely enough for ideas. According to these authors, even though many people try to keep in touch with what is happening close to their own field of expertise and in related areas that seem relevant, they do less often look for other industries that might be experiencing similar problems. For example, bread baking and plastic foam manufacture are both concerned with the expansion and hardening of paste-like materials into solids. Yet, plastic foams technologists rarely attend the meetings of baking technologists to see if they might get any new ideas. Evidence gathered during the course of our case studies corroborates this assertion as it was observed that many entrepreneurs, managers and technicians do not really know what their area's firms in other industries are about. Perhaps this is so because the peculiarities of each specialty that has its own vocabulary, culture and know-how that are not easily communicated to outsiders. It might also be that the probability of hitting upon a "big idea" in a remote technological area that might have short-term pay-off is simply too small for individuals who are otherwise very busy with their regular tasks.

While finding ways to make connections between different local industries might go a long way toward helping people see some new opportunities, overcome barriers and built on local strengths, it seems unlikely that people who are currently involved on a full-time basis in any line of work will have the opportunity to spend much time looking for ideas in remote fields. The key to increase the current level of the exchange of ideas between different industries (whatever it may be) would then have to involve people who are both knowledgeable about particular industrial and commercial practices and who have enough time to visit plants in other industries and think about new applications for their particular expertise. For obvious reasons, retired

people would seem logical candidates to fill in that role, for even though their knowledge base might be not be the most updated in their particular line of work, it might nonetheless prove sufficient to be useful in other industries. Furthermore, they might have the ability to open the doors of various executives that might otherwise remain closed, while their network of knowledgeable individuals that could facilitate new combinations might be very extensive.

Perhaps then an attempt could be made to create or build upon existing inventors or retired people associations or networks to take a first step in this direction. In essence, retired industry personal with a proven track record of creative thinking could be encouraged to visit industrial facilities operating in sectors other than the ones they are familiar with. If this could be achieved, perhaps these outsiders with time and expertise at hand could suggest new ways of improving manufacturing processes or act as intermediaries between different industries. They might make themselves available as consultants if an approach seems particularly promising, or at least force some people to rethink widely held beliefs. While the particulars of such a strategy would have to be worked out in some detail for lack of precedents to build upon, we believe that such an approach might prove a more effective way to increase local networking and the innovative capacity of firms than previous approaches such as "industrial clusters."

Conclusion

One of the least controversial aspects of technological change is that problems are solved through the combination of previously unrelated things. Despite the fact that specific materials, products and processes have always cut across "industrial sectors," specialization has long been held by students of regional growth as the optimal economic setting to promote development and growth. One of the few authors to strongly dissent from that view is Jacobs (1969) who argues, among other things, that local diversity increases the probability of

combining different resources. Further study of human creativity and technological innovation suggest that a diversified city is likely to facilitate the transfer of know-how from one area of industry to others that are unrelated in terms of final products. By offering a greater number and variety of problems to be solved, as well as a much wider pool of expert knowledge and other resources, a diversified city can only increase the probabilities of new combinations. A better understanding of the ways by which creative individuals combine existing resources in different configurations, however, requires that familiar research designs be reconsidered and at the very least supplemented by insights derived from until now unrelated fields. Until this is done, however, there might be some opportunities to increase knowledge flows between industries by tapping into the accumulated expertise of some individuals.

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INTERVIEW TEMPLATE (Summary)

1. Individual's Profile

- 1.1 Personal information
Name, date of birth, current address, education and training
- 1.2 Recent work experience
Entrepreneur, Owner, Employee
- 1.3 Involvement in research project
Individual inventor, teamwork, consultant
- 1.4 Expectations for innovation

2. Invention/Innovation

- 2.1 Factual information
Need/problem to be solved, when did it begin, type of invention (product, process, etc), stage of development
- 2.2 Main characteristics
Description, vs alternatives, main application, potential applications
- 2.3 Development process
- 2.4 Manufacturing process
- 2.5 Getting to the market

3. Creative Process

- 3.1 Previous experience and invention/innovation(s)
- 3.2 Learning and discovery process in this case
Memory, visual thinking, search procedures, collaboration with other individuals
- 3.3 Adaptation of previous know-how to solve new problems
- 3.4 Borrowing ideas and know-how to solve a problem

4. Location and Innovation

- 4.1 Factual Information
- 4.2 Subjective perceptions